research review

OFFICE OF AEROSPACE RESEARCH

OAR: The Research Agency
of The United States Air Force

VOLUME VI NUMBER 12 DECEMBER 1967

Changing Landforms of the Southwest

TERRESTRIAL SCIENCES LABORATORY, AFCRL

A visitor to the arid regions of Arizona, Nevada and New Mexico may see the empty, eroded terrain as ancient landforms, unchanged from some distant geologic age. If the visitor is of a certain temperament, he may even draw substance from a sense of enduring stability in a world where much is impermanent.

In these circumstances, it would be remiss to inject disenchanting fact. But the fact

Figure 1. Large desiccation fissures at Edwards Air Force Base, California.

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is that much of this desolate terrain--and, in particular, the hundreds of vast, flat, dry lake beds--is the most changeable and dynamic of all the world's landforms. In the short period since about 1880, gross changes have occurred.

In an article published in the September issue of the Journal of Geology, Capt. James T. Neal of AFCRL and Ward S. Motts of the University of Massachusetts review recent changes in the dry lake beds of the Southwest. The article is based on the study of some 33 playas. A "playa" is defined as a dry lake bed or any smooth, barren surface with a low, topographic gradient. The best-known (although not typical) playa is the Bonneville Salt Flats.

Most of the playas studied are relics of Pleistocene lakes--lakes that existed during a period extending from 200,000 to 10,000 years ago, just yesterday in geological history. Within the past 100 years, however, the character of the playas has altered greatly.

Why have such dynamic changes occurred only recently? The changes began with the termination of the so-called "Little Ice Age." The Little Ice Age began in about 1600 and lasted until about 1850 or 1900. Its ending was marked by warmer temperatures, greater evaporation, and less precipitation. A collaborating sequence of factors then reinforced and accelerated the process of landform alterations. The settlement of man with associated overgrazing and well drilling was a large contributor. When water tables are lowered by pumping, the capillary zone is correspondingly lowered and this affects vegetation cover. Infiltration of rainwater is decreased and the quicker runoff of precipitation brings rapid erosion. Arroyo formation and cutting have increased markedly

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OAR RESEARCH REVIEW is published monthly by the Office of Scientific and Technical Information (RRYC), Hq Office of Aerospace Research, USAF, 1400 Wilson Boulevard, Arlington, Va. 22209. The objective of this publication is to make a positive contribution to the exchange of information concerning Air Force conducted and sponsored research activities.

JACOB SEIDEN Editor

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since about 1880 through this sequence of casual relationships.

In addition to vegetation changes and arroyo cutting, there have been many other observable geomorphic changes during the past 100 years. One has been the expansion of playas, another the occurrence of mounds, some as high as 10 feet arrayed in vast fields of hundreds of acres. One type of such mound field develops when the root structure of plants holds the soil while adjacent soil erodes away. Another major change has been the development of wide, deep desiccation fissures in the soil.

These giant fissures are of special interest to AFCRL. AFCRL's involvement in the geology of the Southwest stems from a program to identify and catalogue areas that might serve as natural emergency landing areas for Air Force operational aircraft. Since the early 1950's, increasing numbers of these cracks--giant desiccation polygons--have been observed. These polygons range in width from 90 to 1,000 feet, with the average size being about 225 feet.

An example of the recent nature of polygon formation is to be found at Edwards Air Force Base. (Figure 1) This Base is adjacent to Rogers Playa where numerous runways cross the playa surface. Prior to 1945, there were no cracks in the playa. Since that time cracks have opened systematically. Unusually large and deep fissures have opened at Rogers Playa over a 3-year period beginning in 1962, some of them being 3 feet wide and 15 feet deep. ☆

Capt James T. Neal received his B.S. in 1957 and his M.S. in 1959, both in Geology and both from Michigan State University. Before entering upon active duty with the Air Force in 1960, he had begun work toward his Ph.D. under the supervision of the Air Force Institute of Technology. He has continued his studies at Boston College.

Capt Neal has conducted a study of potential new work in the earth sciences with possible application to Air Force needs. He is presently assigned to the Geotechnics Branch, Terrestrial Sciences Laboratory, AFCRL, as Project Scientist for Geologic Properties. His current research interests are centered on dry-lake-bed and remote-sensor studies. He is a member of RESA, Sigma Xi, Sigma Gamma Epsilon, the American Geophysical Union, the American Association for the Advancement of Science, and the Mineralogical Society of America.

power from eleven satellites

SPACE PHYSICS LABORATORY, AFCRL

Over the past two years, the Defense Department has put 18 military communications satellites in orbit. They are distributed in a belt above the equator at altitudes ranging from 36,000 to 39,000 km. There they drift slowly from west to east at the rate of about 20 degrees longitude a day. At least one satellite is always visible for relay communications.

Are the satellites putting out the radiated power they were designed for? This consideration led to a DoD request that AFCRL calculate the telemetry signal strengths from the satellites. Calculations for 11 of these satellites have recently been made by Frederick F. Slack of AFCRL. Measurements of signal strengths of these 11 satellites were accomplished at 401 MHz using the 84-foot parabolic antenna at the Sagamore Hill Radio Observatory.

Data of interest are the satellites' effective radiated power (e.r.p.) which is a quantity difficult to measure from the ground. The task involves quite a bit more than pointing the antenna at each satellite and plotting signal strengths on strip charts. To make effective radiated-power measurements, one must know first of all the efficiency of the ground receiving antenna at the 401-MHz satellite transmission frequency. In the AFCRL measurements, this was determined by using the natural radio source, Cassiopeia A, whose radiation flux is known with great precision as a standard. A complex set of relationships governs the calculations of antenna temperature. Figures for these antenna parameters become a part of a larger equation that includes the received power from the satellite and the satellite range. The resultant calculations give the effective radiated power.

The 84-foot parabolic dish uses a rotary feed for polarization peaking, a 401-MHz, 2-db preamplifier located at the feed, and a Telco converter associated with a Collins receiver. The quantity measured was the signal strength at the preamplifier. Of the 11 satellites measured to date by AFCRL, 9 have effective radiation power within a narrow range of 230 to 288 mw, 1 has an e.r.p. of 162, and only 1 is way down on the scale with an e.r.p. of 10. The remaining 7 of the 18 military communications satellites will be calibrated soon.

AFCRL has pioneered in the calculation of e.r.p. from satellites using radio stars as primary standards. A large number of such measurements have also been made of the radiated power of commercial communications satellites. ☆

Mr. Frederick F. Slack has been a research electronic engineer with the Radio Astronomy Branch, Space Physics Laboratory, AFCRL since 1964. His responsibilities include the design of systems and special electronic circuits for use in ionospheric research programs. One of the systems he has designed is a multistation network for determining the size, direction, and velocity of drifting irregularities in the ionosphere.

Since joining AFCRL in 1945, he has been associated with the Volscan Section, the Astrosurveillance Sciences Laboratory, and the Special Systems Laboratory. While with the Volscan Section he designed the first operational track-while-scan system and the light gun for use in an air traffic control system. He has also been engaged in the design and development of techniques for the detection of aerospace targets and the processing of associated data.

LASER SYSTEM for LUNAR RANGING

MAHLON S. HUNT
Terrestrial Sciences Laboratory, AFCRL

AFCRL is developing a laser system for detecting small variations in the moon's motion, and for measuring earth-moon distances to within two meters. The system involves placing a reflector on the lunar surface, directing a laser beam to it, and detecting the reflected light.

Two experiments are under consideration, one ranging, the other photographic. For the ranging experiment, a 10-joule ruby-laser pulse is transmitted from the ground through a special-purpose telescope with a 1.5-meter aperture. It is returned from the lunar reflector back through the same telescope to a photomultiplier. The reflecting element may be either a diffraction-limited cube corner with an aperture of 11 cm, or an array of several smaller reflectors. The design criterion for the ranging experiment is that an average of 100 photons be returned through the telescope per pulse, assuming that observatory seeing is typical and that light-velocity aberration displacement is not more than 1 arc second. The laser is designed with

Mr. Mahlon S. Hunt is a research geodesist with the Geodesy Branch, Terrestrial Sciences Laboratory, AFCRL. After serving with the Navy during World War II, he attended Washington University, St. Louis, Missouri, where he received his A.B. (1949) and his A.M. (1952), both in Geography. After employment with the Aeronautical Chart and Information Center and the Naval Observatory, he joined AFCRL in 1959. Mr. Hunt serves as project scientist for extraterrestrial geodesy studies, with areas of interest including selenodesy, lunar laser experiments, astrodynamic constants, space referencing systems, and aerospace geodesy instrumentation. He is a member of Sigma Xi, and has published frequently in the technical area of selenodesy and related fields.

a 10^{-8}-second pulse duration and will be used in its Q-switched mode for range measurements.

For the photography experiment, a 40-joule laser signal is transmitted through the special-purpose telescope but it is returned by the reflector to a separate general-purpose telescope with an aperture of 1.5 meters. This second telescope is displaced approximately 1.5 km to the east of the transmitting telescope. This displacement compensates for relative transverse velocities between the earth and moon.

There are many uses for precise information on the range to a specific point on the lunar surface. For example, laser observations throughout the lunar libration cycle could give independent checks on the moon's mechanical figure and provide observations useful in calculating an improved physical ephemeris of the moon. Such observations could also provide an independent check on the earth's equatorial radius, and on lunar theory dealing with the eccentricity of orbits.

AFCRL and NASA are working jointly on the experiment. ☆

ROCKETS AND ARECIBO RADIO TELESCOPE USED IN JOINT EXPERIMENTS

UPPER ATMOSPHERE PHYSICS LABORATORY, AFCRL

In October 1967, AFCRL conducted a series of rocket experiments in Puerto Rico, making simultaneous observations of the ionosphere by rocket instruments and by the 1000-foot Arecibo radio telescope.

The experiments had three basic purposes: 1) to acquire data on the ionosphere's E and lower F regions and sporadic E at tropic latitudes; 2) to measure rapid changes in ionization and the decay of the E region at

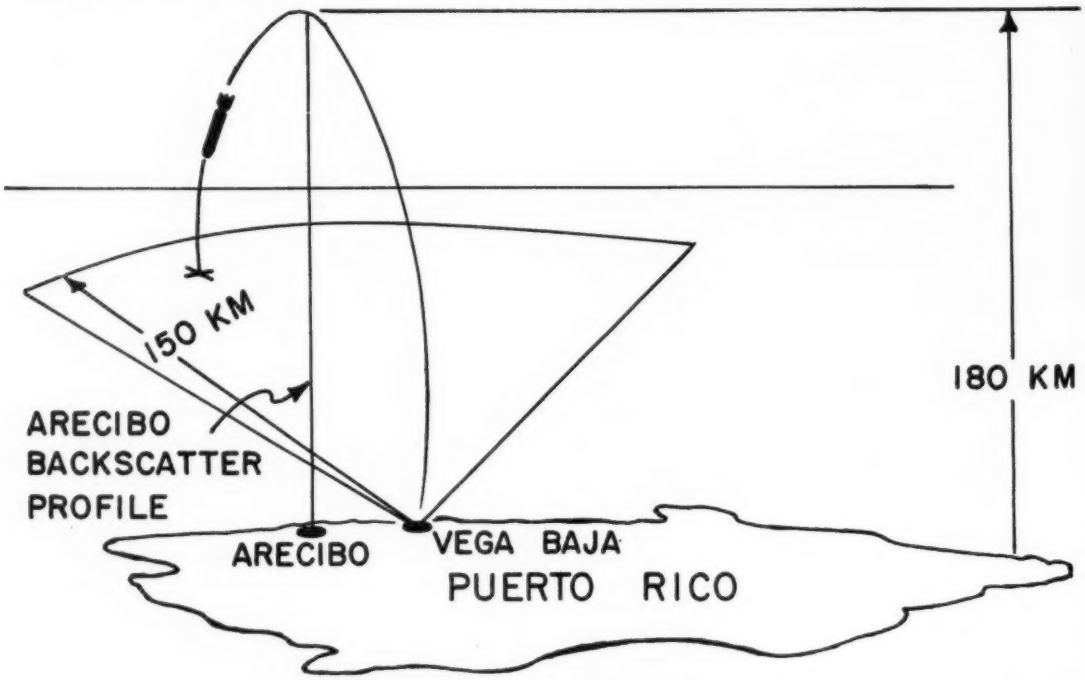


Figure 1. Rocket tiring configuration.

night; and 3) to compare charged-particle data obtained in situ by means of instrumentation aboard the AFCRL rockets with data from the ground using the Arecibo telescope. Rocket measurements included temperature, energy distribution, and the density of ions and electrons. These measurements provided a basis for the calibration and interpretation of ionospheric data acquired by the Arecibo radio telescope.

AFCRL launched five Nike-Iroquois (NIRO) rockets in the test series. The rockets were launched in a northwesterly direction from Vega Baja, Puerto Riço. They were designed to reach a peak altitude of about 180 km on a trajectory terminating in the ocean 150 km from the launch site. (Figure 1.) The Arecibo radio telescope, operated by Cornell University, was pointed to intercept the rocket flight trajectory. Launchings were made in late October over a 3-day period.

The over-all program was under the direction of Rita C. Sagalyn, AFCRL's project scientist. A similar series of experiments was successfully conducted by AFCRL from Vega Baja in February 1966. ☆

Mrs. Rita C. Sagalyn is Chief of the Space Electricity Group, Upper Atmospheric Physics Laboratory, AFCRL. She received a B.A. in Physics from the University of Michigan in 1948, and an M.S. in Physics from Radcliffe College in 1950. She has been with AFCRL since that time. Mrs. Sagalyn is presently studying the electrical properties of the upper atmosphere and interplanetary gas. Experiments have been designed and flown on a variety of rockets and satellites for the study of ambient charged-particle densities, electric currents, and electric fields in and above the ionosphere. Mrs. Sagalyn received the Guenter Loeser Award in 1958 for her work in the lower atmosphere, and the Patricia Kayes Glass Award in 1966 for her outstanding work as a woman scientist. She is a member of RESA and the American Geophysical Union.

atmospheric luminescence experiments in Australia

OPTICAL PHYSICS LABORATORY, AFCRL

AFCRL and Australian scientists will soon bring together two unique research facilities in a joint series of experiments to measure the luminescence of the night sky.

The huge 70-acre antenna of New England University, New South Wales, and AFCRL's KC-135 atmospheric optics flying laboratory will be used in the two-week observation program that will begin in early 1968. The University antenna (a large dipole array) will be used to direct a narrow beam of radio energy into the ionosphere to irradiate atmospheric molecules. Certain of these molecules, when excited by the radio energy, emit infrared energy.

The infrared energy emitted by these excited molecules will be measured using instrumentation carried to an altitude of 12 km aboard the KC-135. Aboard this aircraft is a great variety of instrumentation--spectrometers, interferometers, radiometers, and associated data-recording equipment--for making measurements of atmospheric radiance. The aircraft observational program is under the direction of Dr. A. T. Stair, Jr. and Major W. F. Grieder of AFCRL.

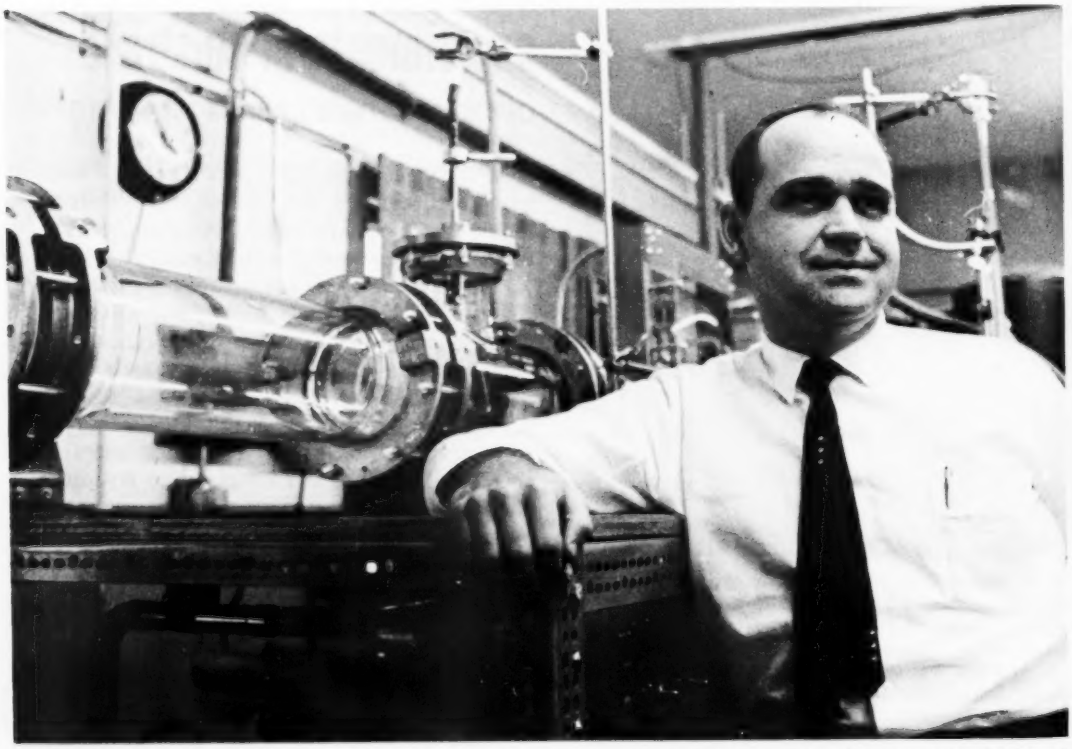
Experiments will be made at night because the very weak emissions that scientists hope

to detect occur mostly in the infrared where they would be saturated by the normal solar scattering of the sky during the daytime. Also, the powerful 500-kw transmitter used to irradiate the atmosphere operates at 1.515 MHz, which is within the standard broadcast band and thus might interfere with normal daytime broadcasting.

The antenna will irradiate a region of the ionosphere about 2 km thick at about 90-km altitude. Of the many different types of molecules that comprise the earth's atmosphere, the one which is expected to radiate infrared energy most strongly at this altitude is OH, sometimes referred to as the hydroxyl radical. Infrared energy from this molecule will be measured in the spectral region of from 0.5 to 8 microns. Although 0.5-micron radiation is visible as light, the light emissions will be too faint to be seen from the ground.

The Australian and AFCRL scientists are seeking to explain the mechanisms of airglow, the faint luminous light of the sky seen on dark, clear nights. The OH molecule is one of several atmospheric molecules that absorb energy and re-emit it to produce the luminescence phenomenon.

During the two-week expedition to Australia, the KC-135 will be based at the Kingsford-Smith Airport in Sydney, 200 miles from the New England University transmitter. The aircraft will be serviced by personnel of Qantas International Airlines.☆



Dr. Alva T. Stair, Jr. is a research physicist with the Radiation Effects Branch, Optical Physics Laboratory, AFCRL. He received his B.S. in Mathematics in 1952, and his Ph.D. in 1956, both from the University of Oklahoma. In 1958, after serving in the Air Force as a physicist, he remained as a civilian scientist, and participated in the analysis of thermal data from high-altitude nuclear bursts, with emphasis on the infrared spectral region. He has designed and built experimental apparatus for the study of infrared radiation from inelastic collisions of electrons with gases, and from gas kinetic reactions among atmospheric species. Dr. Stair's work has also included an investigation of infrared radiation from missile exhausts. He is a member of Phi Beta Kappa, RESA, Sigma Xi, the Optical Society of America, the American Institute of Physics, and the Faraday Society.

Maj William F. Grieder is an electronics engineer with the Radiation Effects Branch, Optical Physics Laboratory, AFCRL, where he has been assigned since 1964. He serves as Project Officer for a major research program on the optical and infrared effects of nuclear weapons. In previous assignments he was a jet interceptor pilot in the Air Defense Command, and a project engineer at the Air Proving Ground Center, Eglin AFB, where he tested and evaluated USAF airborne radar and infrared augmentation devices. Major Grieder received a B.S. in Electrical Engineering and a B.S. in Mechanical Engineering, Aeronautical Option, from North Carolina State College in 1959. The Air Force Institute of Technology awarded him an M.S. in Astronautics in 1964. He is a member of Eta Kappa Nu, Pi Tau Sigma, Tau Beta Pi, and Phi Kappa Phi.

combinatorial theory

MAJOR WILLIAM R. TROTT
Directorate of Mathematical Sciences, AFOSR

Combinatorial analysis, or combinatorial theory as it is commonly called today, is a mathematical discipline that had its origin in ancient times. According to legend the Chinese Emperor Yu (2200 B.C.) observed the Magic Square

$$\begin{bmatrix} 4 & 9 & 2 \\ 3 & 5 & 7 \\ 8 & 1 & 6 \end{bmatrix}$$

on the back of a divine tortoise. Permutations had a feeble beginning in China before 1100 B.C., and Rabbi Ben Ezra (1140 A.D.) seems to have known the formula for the number of combinations of n things taken r at a time. Much of the earliest work in the field was tied to number mysticism.

Gottfried Wilhelm Leibnitz was the first author to use the term "combinatorial" in its present mathematical sense. Leibnitz was scarcely twenty years old when he wrote his "Dissertatio de Arte Combinatoria," printed in 1666. In this dissertation Leibnitz illustrated the application of combinatorial techniques to a broad spectrum of subjects. Today a much larger number of applications can be found for combinatorial theory and its techniques. A few of these will be mentioned later.

A formal definition of combinatorial mathematics is difficult, since the theory associates with so many subdivisions of mathematics. In simple and by no means complete terms, however, combinatorial theory is concerned with the study of arrangements of elements into sets. The elements are usually finite in number, and the arrangement is restricted by certain boundary conditions imposed by the particular problem under investigation. However, the reader should be cautioned against assuming that combinatorial theory is strictly limited to

the study of finite sets. An infinite class of finite sets is no longer a finite set, and infinity has a way of getting into the most finite of considerations.

Nowhere more than in combinatorial theory do we see the fallacy of Kronecker's well-known saying that "God created the integers, everything else is man-made." A more accurate statement might be: "God created infinity, and man, unable to understand infinity, had to invent finite sets." In the ever-present interaction of finite and infinite lies the fascination of all things combinatorial.

The program of the Mathematics Division, Directorate of Mathematical Sciences, AFOSR, concerns itself with basic research in analysis, functional analysis, partial differential equations, and statistics and probability. Included in these diverse interests is the area of combinatorial mathematics and its application to matters affecting the Air Force. With support from the Mathematics Division, the Department of Statistics at the University of North Carolina at Chapel Hill has been very active in the field of combinatorial theory. In April of this year the Department held an AFOSR-sponsored Symposium on Combinatorial Mathematics and its Applications, at which numerous papers dealing with problems in finite geometry, group theory, graph theory, experimental design, coding and information theory, and automata research were presented. All of the problem areas discussed at the Symposium are related in that their solution depends upon progress in combinatorial mathematics. Most of these areas are of importance in advancing Air Force technology.

Combinatorial theory is a prime example of a mathematical discipline that until recently has been regarded primarily as a recreational pastime. It has now been injected into the mainstream of mathematics, however, and has contributed heavily to the solution of many so-called "unsolvable" applied problems. In fact, combinatorial theory has mothered some of the more active branches of today's mathematics. Such a branch--perhaps the most successful one--is algebraic topology, which the French mathematician Henri Poincaré raised from the status of little more than recreational mathematics in the nineteenth century to that of an independent geometric discipline. From 1910 to the present, several other mathematicians, among them outstanding Americans such as Alexander, Lefschetz, Veblen and Whitney, took up Poincaré's ideas and developed topological methods to a degree of perfection that can be compared with the achievements of the finest electron microscope in cellular biology. Homology theory, the central part of contemporary topology, stands today with quantum optics as one of the two greatest achievements in pure thought in this century, and the first that bears a peculiarly American imprint. Algebraic topology has been unexpectedly successful in solving an impressive array of long-standing problems ranging over mathematics and, in the last few years, even into physics. It holds promise of future successes in physics.

To complete this discussion, two selected problems will be presented with the intent of providing the reader some insight into the beauty of combinatorial techniques.

1. The Ising problem. A rectangular M x N grid is made up of unit squares, each colored either red or blue. How many different color patterns are there if the number of boundary edges between the red squares and the blue squares is prescribed?

This frivolous-sounding question happens to be equivalent to one of the most worked-on problems in the field of statistical mechanics. This is the explanation of the behavior of matter on the basis of known facts at the molecular or atomic levels. The Ising problem, of which the above statement is one of many equivalent versions, is the simplest model that exhibits the macroscopic behavior expected from certain natural assumptions at the microscopic level. A complete and rigorous solution of the problem was not achieved until the last three years, although the main ideas had been conceived many years before. The combinatorial arguments used for solving the problem involve an unexpected application of Grassman algebras.

2. Percolation theory. Assume one is given an orchard of regularly arranged

fruit trees. An infection is introduced in a few trees and spreads from one tree to an adjacent one with probability p. How many trees will be infected? Also, will the infection assume epidemic proportions and run through the entire orchard, leaving only isolated pockets of healthy trees? Further, how far apart should the trees be spaced to ensure that p is so small that any outbreak is confined locally?

At first glance, this problem might seem to be of interest only to the fruit grower. However, consider the following important problem in applied science: Assume a crystalline alloy of magnetic and nonmagnetic ions in the proportions p to q. Adjacent magnetic ions interact, and so clusters of different sizes have different magnetic susceptibilities. If the magnetic ions are sufficiently concentrated, infinite clusters can form, and at a low temperature long-range ferromagnetic order can spread through the whole crystal. Below a certain density of magnetic ions, no such ordering can take place.

The problem of the orchard and the problem of the crystalline alloy are one and the same. The solution has been found by translating the problem into the language of graph theory and developing a beautiful theory on the borderline between combinatorial theory and probability.

Examples 1 and 2 are only two of a long list of varied problems that can be tackled by the use of combinatorial methods and that have application to problems faced by scientists today in many different fields. The implication seems to be that in many areas of mathematics, physics, and the life sciences, further work in combinatorial theory is a necessary condition for progress. Therefore it seems obvious that in the next few years there will be considerable activity in combinatorial theory and that, in university curricula as well as in research, the mathematics of the discrete will come to occupy a position at least equal to that of the applied mathematics of the continua.

In keeping with this line of thought and with the policy of supporting research that promises large contributions to Air Force technical goals, AFOSR will sponsor in 1968 a special research effort focused on combinatorial mathematics and its applications. The purpose of this effort is to take immediate steps toward solving several outstanding practical and theoretical problems in that branch of mathematics called combinatorial theory. Topics to be studied relate to the discrete phenomena problems in molecular biology, genetics, statistical mechanics, molecular and atomic phenomena, probability, logic, and computer theory and technology. The Department of Statistics, University of North Carolina, will conduct the program. Because of the Department's keen interest in combinatorial mathematics and its past outstanding performance in this area, the prospects appear good for significant advances in the status of combinatorial theory and in Air Force technology as well.

ACKNOWLEDGEMENT

Many of the ideas in this article, and in particular the two examples, have been contributed by Professor Gian-Carlo Rota. They were provided in conjunction with AFOSR Grant AF-AFOSR-1201-67.

REFERENCES

(1) Pólya, G. et al., Applied Combinatorial Mathematics, edited by E. F. Beckenback, New York: John Wiley and Sons, Inc., 1964.

(2) Ryser, H. J., Combinatorial Mathematics, Carus Mathematical Monograph No. 14, Buffalo, N.Y.: The Mathematical Association of America, 1963 (distributed by John Wiley and Sons, Inc., New York).

BARIUM CLOUD RELEASES

UPPER ATMOSPHERE PHYSICS LABORATORY, AFCRL

Two Nike Tomahawks were fired from Wallops Island, Virginia, on October 4 and 5, 1967, to release barium vapor into the ionosphere. The program had several purposes. One was to measure the relative motions of ionospheric winds and the winds of neutral particles of the upper atmosphere. Because of the effect of the earth's magnetic field, charged-particle motions and neutral constituent motions are not necessarily the

same. Another purpose was to measure the radio energy attenuation of the patches of enhanced ionization created by the barium.

Each rocket released 3 barium puffs during ascent at altitudes of 120, 180 and 220 km. Carried aboard each rocket was a cw 4-frequency phase-coherent transmitter operating at 36.4, 72.8, 145.7 and 583.0 MHz. An array of ground-based receivers, radars and cameras monitored the releases. Radar tracking was done in the Cape Kennedy, Washington, D.C., and Massachusetts areas.

Following the release of the barium vapor, a plasma of Ba^+ and free electrons was formed. Tests consisted of measuring the attenuation of RF signals passing through the plasma. The plasma's reflection and scattering cross section were also measured. Dr. N. W. Rosenberg is the project scientist. ☆

Dr. Norman W. Rosenberg is Chief of the Ionospheric Perturbations Branch, Upper Atmosphere Physics Laboratory, AFCRL, where he is responsible for studies of chemical-release techniques for geophysical research in the upper atmosphere. These releases have led to new knowledge on winds, temperatures, composition, and structure of the ionosphere.

Dr. Rosenberg was graduated from the University of Wisconsin in 1944 with a B.S. in Chemistry. He took his M.S. and Ph.D. in 1949 from Harvard University, specializing in reaction kinetics. Prior to joining AFCRL, he was associated with Ionics, Incorporated, where he was Director of Research. His work at Ionics included studies on water desalination and electrochemical processes, and resulted in the issuance of about 20 patents.

Dr. Rosenberg is a member of RESA, the American Chemical Society, and the Federation of American Scientists. He has a number of publications to his credit.

LOW-COST ROCKET SYSTEM FOR ATMOSPHERIC DENSITY MEASUREMENTS

AEROSPACE INSTRUMENTATION LABORATORY, AFCRL

AFCRL has tested a low-cost rocket system for measuring atmospheric densities above 100 km. The new system is an adaptation of a system originally developed by AFCRL for launch aboard large rockets of the Nike-Cajun class. Redesigned to be flown aboard smaller, less expensive meteorological rockets, the system was successfully tested for the first time aborad a Sparrow Arcas vehicle on September 9, 1967. Using these smaller rockets, the cost of each density-measuring experiment can be cut more than 50 percent.

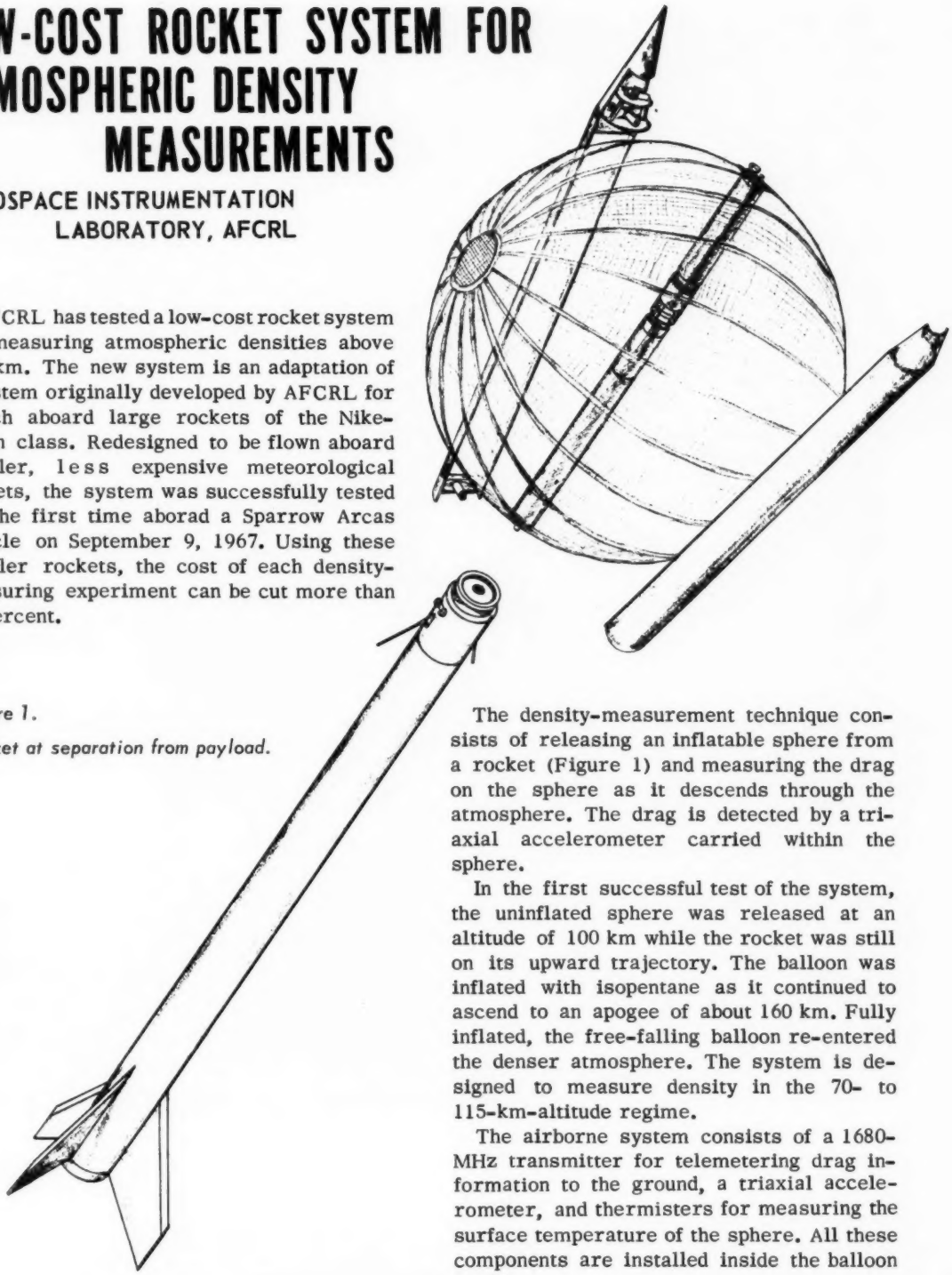


Figure 1.

Rocket at separation from payload.

The density-measurement technique consists of releasing an inflatable sphere from a rocket (Figure 1) and measuring the drag on the sphere as it descends through the atmosphere. The drag is detected by a triaxial accelerometer carried within the sphere.

In the first successful test of the system, the uninflated sphere was released at an altitude of 100 km while the rocket was still on its upward trajectory. The balloon was inflated with isopentane as it continued to ascend to an apogee of about 160 km. Fully inflated, the free-falling balloon re-entered the denser atmosphere. The system is designed to measure density in the 70- to 115-km-altitude regime.

The airborne system consists of a 1680-MHz transmitter for telemetering drag information to the ground, a triaxial accelerometer, and thermisters for measuring the surface temperature of the sphere. All these components are installed inside the balloon itself.

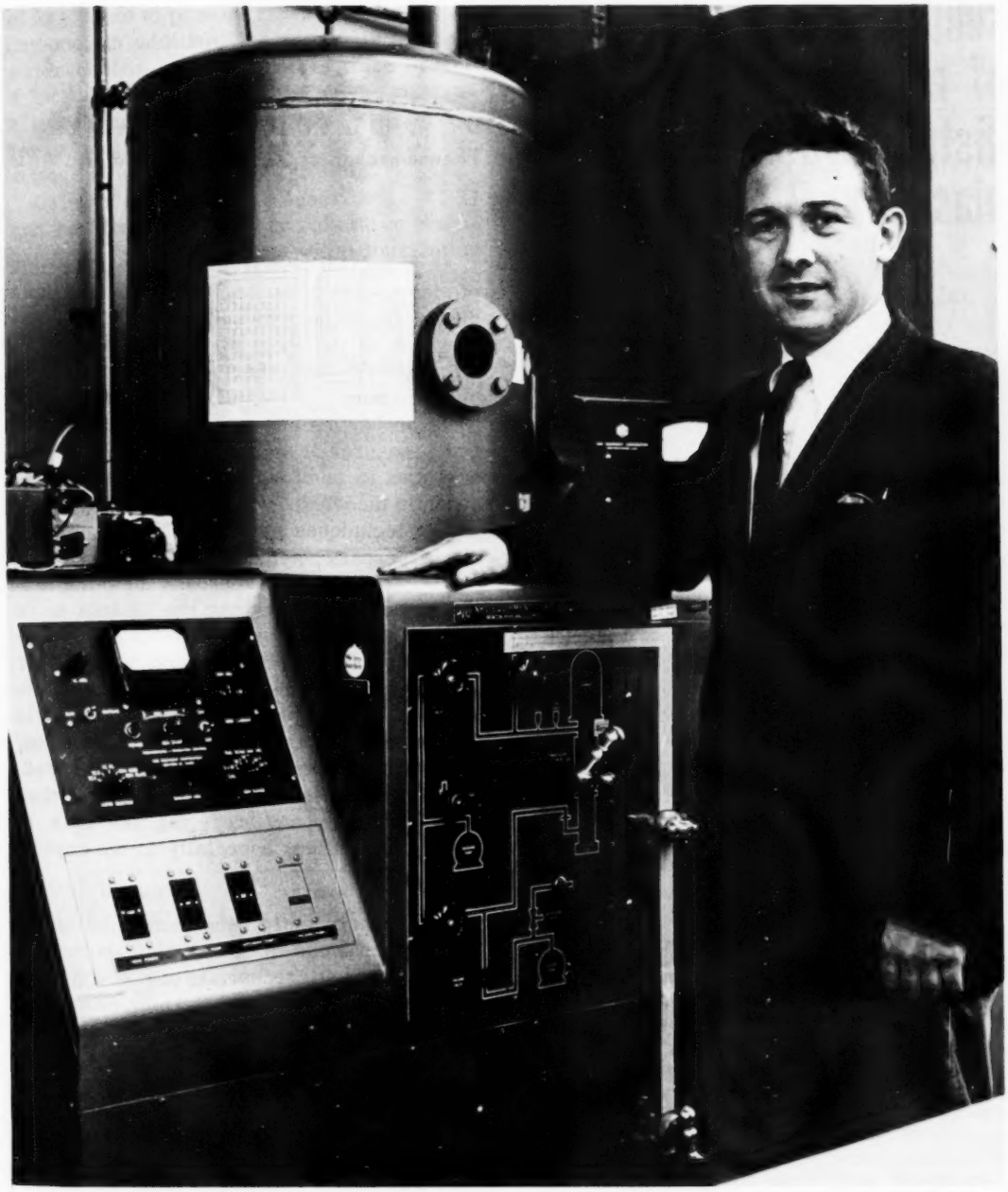
The successful September 9 test was the first known measurement of density above 100 km using this smaller class of rockets. The technique is designed to provide the Air Force with a method for obtaining synoptic measurements of upper-atmosphere densities at its missile ranges. It will also be used as one of several techniques employed by AFCRL to obtain precise data on diurnal, seasonal and geographic variations in atmospheric density.

The new system was developed by G. A. Faucher, J. F. Morrissey and R. V. Matson of AFCRL. ☆

Mr. Gerard A. Faucher (right) and Mr. Roland Matson are with the Direct Sensing Techniques Branch, Aerospace Instrumentation Laboratory, AFCRL.

Mr. Faucher, a Project Scientist, is presently engaged in determining the density of the upper atmosphere from 80- to 150-km altitude by measuring the drag forces on a falling sphere. He has developed an operational density-measuring system for the 30- to 90-km-altitude region using the Sparrow Arcas rocket. He was graduated from the University of Maine in 1950 with a B.S. in Engineering Physics, and did graduate work at the Massachusetts Institute of Technology in 1953 and 1954. He joined AFCRL in 1950.

Mr. Matson, a Physical Science Technician, is also engaged in determining upper-atmospheric density. His previous experience has included employment by the Massachusetts Institute of Technology, the Sperry Gyroscope Company, the Hughes Aircraft Corporation, and the Atomic Energy Commission. Mr. Matson studied mathematics and physics at Northeastern University from 1963 to 1965.



Mr. James F. Morrissey, Chief of the Direct Sensing Techniques Branch, Aerospace Instrumentation Laboratory, AFCRL, is concerned with the development of meteorological sensors for balloon, rocket, and aircraft use. These include types sensitive to temperature, pressure, humidity, density, and index of refraction. Mr. Morrissey received his B.S. degree from the University of Massachusetts in 1956. From 1956 to 1960, he was associated with the Crosley Research Laboratory, Boston, Mass., and from 1960 to 1961 with AVCO Corporation in Wilmington, Mass. As a systems design engineer with AVCO, he was concerned with the design of electronic and electromechanical instrumentation and systems integration for the Titan and Minute Man missiles. He joined AFCRL at the end of 1961.

simple and novel method of measuring T and σ distribution within a plasma-arc discharge

DR. WARD C. ROMAN
Thermomechanics Research Laboratory, ARL

Dr. Ward C. Roman, a research scientist with the Thermomechanics Research Laboratory, ARL, has been working primarily in the field of magnetohydrodynamics, investigating problems in plasma-arc technology. At present, he is conducting research in high-pressure, high-current plasma arcs under the influence of transverse external magnetic fields and aerodynamic flow.

Dr. Roman received the Bachelor of Mechanical Engineering degree from Rensselaer Polytechnic Institute in 1958. The Ohio State University awarded him the M.S. and Ph.D. degrees in Mechanical Engineering in 1962 and 1966, respectively. Commissioned a second lieutenant in the Air Force upon his graduation from R.P.I. in June 1958, he joined ARL upon his release from extended active duty in June 1962 as a Task Scientist. He is a member of Pi Tau Sigma and Sigma Xi.

An important research objective in the field of plasma-arc technology is to develop simple diagnostic techniques suitable for the determination of the local distributions of electric, kinetic, and thermodynamic states in high-temperature plasmas. Determination of these properties under extreme temperature and pressures at and above atmospheric are essential to complement the many plasmadynamic theories.

Two techniques are available for making the necessary measurements: optical and probe. The optical approach has the advantage of not perturbing the plasma to be studied but usually suffers from the standpoint of yielding only integrated values over a given path length through the plasma. In contrast, the probe techniques may yield information on the local distribution but, unless the probes are highly miniaturized, the plasma is locally disturbed. Nevertheless, obtaining and reducing the data is greatly simplified, especially in the case of asymmetry.

Work has recently been completed at the Thermomechanics Research Laboratory, ARL on diagnostic techniques of atmospheric-pressure d-c arc plasma. (1) By employing several diagnostic techniques, a simple and novel method of measuring the distribution of the temperature (T) and electrical conductivity (σ) within the plasma of an electric-arc discharge has been established. The plasma arc apparatus employed in these tests was previously used at ARL for studying the influence of external transverse aerodynamic and magnetic fields on a plasma-arc column. (2) Basically, a well-type cathode coupled with a helically coiled anode established the free-burning arc geometry. A gas injector surrounded the 2% thoriated tungsten cathode and provided a small amount

of argon gas to prevent rapid oxidation of the cathode. In addition, 2 electrically floating, water-cooled copper locators were spaced 2 inches apart above and below the plasma-arc column test region. The current test range was 200–400 amperes at a total arc voltage of approximately 175 volts.

Using the method to be described, $\sigma = f(T)$ can be determined through only three measurements, namely: (1) the radial distribution of the self-magnetic field, (2) the voltage gradient of the discharge, and (3) the radial distribution of the continuum intensity. A miniaturized Hall-effect element of indium arsenide was used to measure the self-magnetic field from which, using Maxwell's Law, the current density distribution was calculated. (Figure 1.) Because of the low

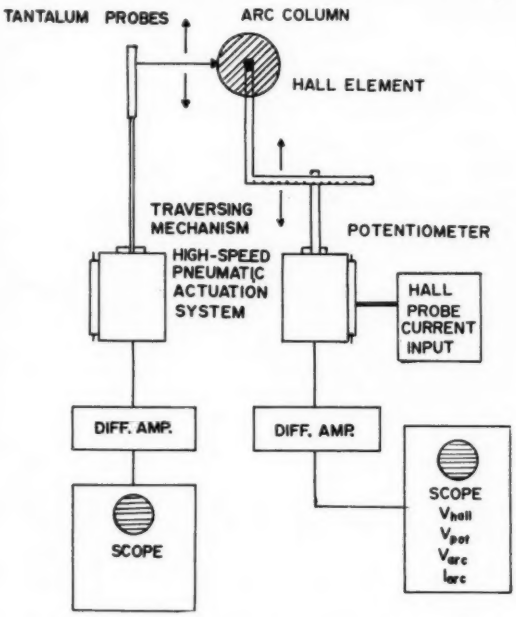


Figure 1. Schematic diagram of potential and Hall-element probe apparatus.

melting point and high temperature coefficient of InAs, a thin heat shield surrounded the probe, providing both thermal and electrical insulation. The probe was traversed through the column using a high-speed, two-way pneumatic cylinder. A linear precision potentiometer attached to the probe-driving mechanism monitored the probe position. The probe diametrically traversed the column midway between the locators at 1.2 m/sec. To verify minimum disturbance, a high-speed camera simultaneously photographed the probe traversing the column from the side and head-on view. The potentiometer output, arc voltage, arc current, and Hall element output voltage (after amplification) were displayed on a dual-beam oscilloscope.

The voltage gradient was determined using two 1/32-inch o-d tantalum probes, separated by 1/2 inch, which were rapidly traversed through the column. After passing through a differential amplifier, the outputs were displayed on an oscilloscope. In addition, data were also obtained using the water-cooled copper locators to measure the potential and by using a 1/16-inch o-d water-cooled copper dual probe at different axial locations.

Because spectrometric measurements require considerable instrumentation and time, a simple optical system was developed at ARL (3) to measure temperature profiles in the 8,000°K to 14,000°K temperature range. (Figure 2.) The method consists of measuring the absolute lateral intensity dis-

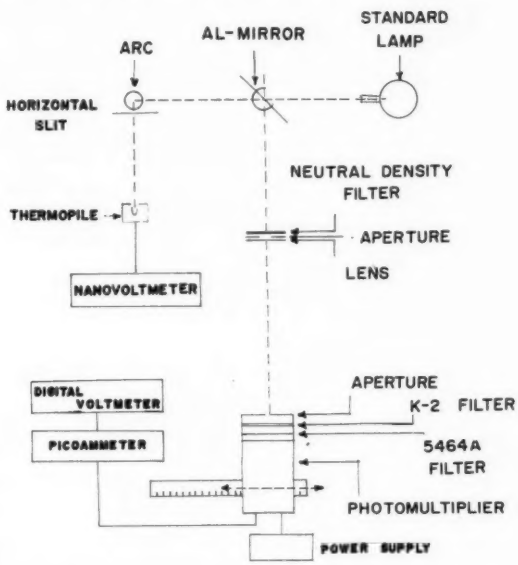


Figure 2. Optical system and instrumentation for temperature determination.

tributions of the continuum radiation using a narrow-band filter system (8-Å half width) and an end-window photomultiplier in a region free from spectral lines. Lateral profiles were reduced to radial distributions by solving the Abel-type integral equation. Temperatures are then obtained by using standard data of absolute continuum radiation as a function of plasma temperature. The lateral scans were achieved by moving the source image over a small aperture or by moving the aperture over the same image in less than one millisecond. Both methods gave consistent results. The system is calibrated with a standard tungsten lamp and, because the continuum radiation is measured, knowledge of the filter transmission, profile, line profiles, and the ratio of line to continuum intensity is not required. Neglecting these relationships in measuring line intensities with filter systems usually leads to large errors. Thus, by placing the standard at the source position, one obtains for the absolute lateral continuum intensity the simple expression $I_p(y)=\frac{G_p}{G_s} I_s(\lambda, T)$ where $\frac{G_p}{G_s}$ is the ratio of output voltages and $I_s(\lambda, T)$ is the spectral radiance of the standard lamp. This technique was verified by comparing the results with measurements achieved with a spectrometer.

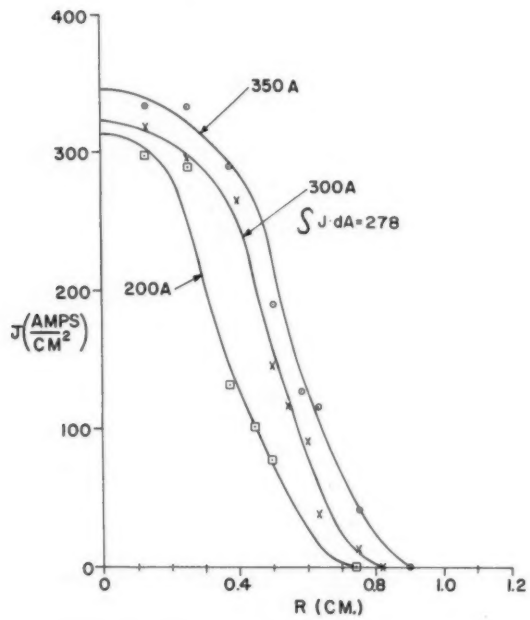


Figure 3. Arc current density as a function of radius.

The preliminary results indicate that the integrated current-density measurements are consistent with the measured total arc current (Figure 3). The sum of the measured energy losses agree, within experimental accuracy, with the power input based on the measured electric-field intensity and arc current. The measured total radiation accounted for approximately 12% of the total power input within the test section for a current input of 300 amperes. The measured temperature distribution (Figure 4) in-

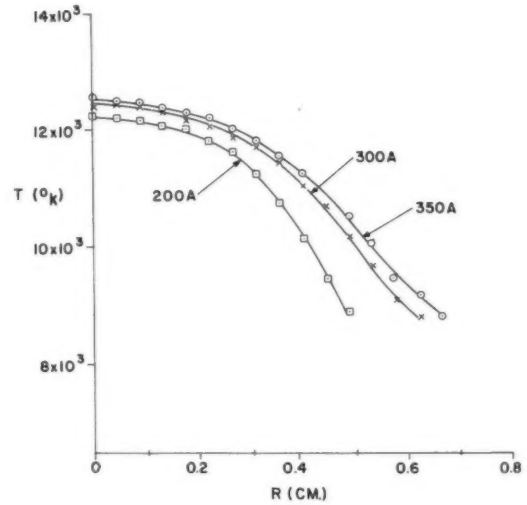


Figure 4. Arc temperature as a function of radius.

dicated a center-line temperature of approximately 12,000°K for the range of arc currents used. From the current density and voltage gradient, $\sigma = f(R)$ was derived. Subsequently, using the temperature profiles determined through the optical technique and available literature data, the $\sigma = f(T)$ was obtained (Figure 5). In addition, the results may be used to obtain values for the total radiation as a function of plasma temperature.

Although this method is not of the highest precision, it is an inexpensive, fast, and sufficiently accurate technique for engineer-

ing applications. Continuing work in the error analysis aspects is in progress at ARL. ☆

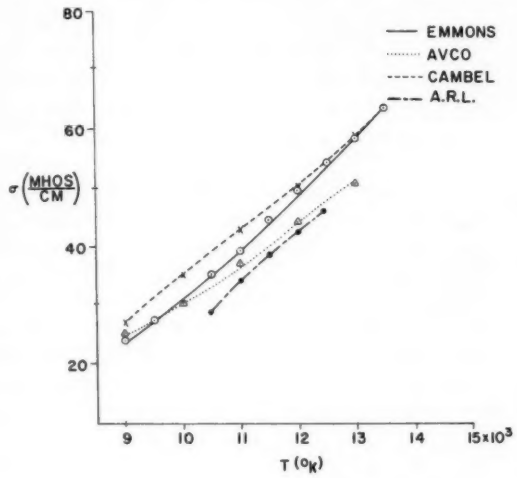


Figure 5. Electrical conductivity as a function of temperature.

REFERENCES

(1) Roman, W., K. Benedetto, and P. Schreiber, "Diagnostic Techniques for Atmospheric Pressure Arc Plasmas," Eighth Symposium on Engr. Aspects of MHD, Stanford University, March 1967.

(2) Roman, W. C. and T. W. Myers, "Investigation of Electric-Arc Interaction With Aerodynamic and Magnetic Fields," ARL 66-0191, October 1966.

(3) Lamb, J. D. and P. Schreiber, "The Application of a Differential Interferometer to an Axially Symmetric Arc-Heated Plasma," ARL 66-0222, November 1966.

FAR-INFRARED SUPPRESSION

CAPTAIN JOHN F. KANTAK
Directorate of Engineering Sciences, AFOSR

A new diagnostic technique which could lead to high-power coherent sources in the far-infrared (FIR) region has been developed. With AFOSR support, Dr. P. D. Coleman of the University of Illinois has successfully used a diffraction grating to make a vapor resonator frequency selective. This was achieved by placing a mechanically tuned grating in a molecular gas laser. This type of suppression is critical to current FIR laser research. The cleaner spectral output and the new higher power levels permit definitive quantitative and qualitative analysis.

Molecular Lasers

The number of substances which produce FIR radiation when they lase is limited because of energy structure constraints. The difference between energy levels governs the frequency of available radiation through the relation $\Delta E = h\nu$ (h = Planck's constant, ν = frequency). Simpler elemental lasers typically do not produce FIR radiation because of their energy level separations. FIR wavelength (20 - 1000 microns) emissions are more easily obtained from molecular lasers because they possess the proper energy-level separations. Dr. Coleman, under contract to the Air Force Office of Scientific Research, is studying molecular gas lasers employing water, deuterium, and organic vapors as the lasing media. The radiation covers a broad range of frequencies which are a conse-

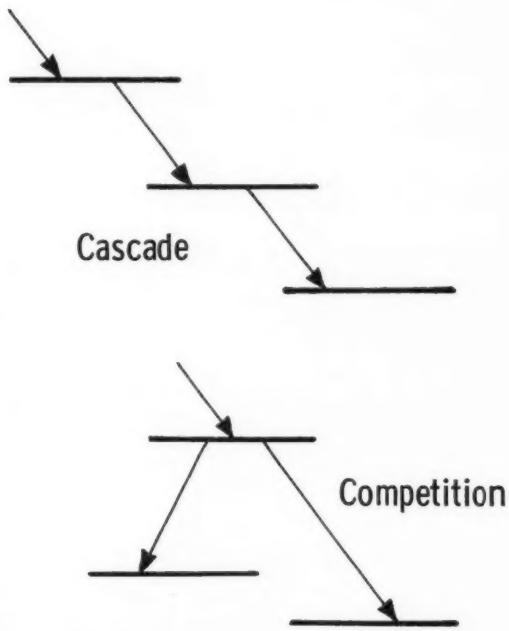


Figure 1. Line-to-line interactions.

quence of the large number of transitions possible in the inverted gas. This broad frequency response is characteristic of molecular gas lasers.

Significant power variations occur from pulse to pulse. In addition, unpredictable variations occur during a pulse. This type of radiation does not lend itself to definitive analysis. Individual line spectra interact with each other in the sense that they may use a common energy level in their radiation processes. The two most common line-to-line interactions are called cascade and competition (Fig. 1). In the cascade process, the energy separation between the levels involved is very small and the resultant radiation is generally weak. The suppression of the initial step of this process is likely to prevent the subsequent radiation. This phenomenon can be used as a diagnostic tool in that particular lines in a cascade process may be matched against a molecular energy-level model. This is an excellent tool for defining the lasing specie and process. In the competition process, two or more distinct radiations are caused by transitions from the same energy level. This competition detracts from the power of each of the radiations. Competition is wasteful in that the pumping energy is rapidly dissipated in unproductive transitions. Since high-power lasing sources are the purpose of this research, the need exists to suppress these interactions and thus provide greater output power.

To study molecular lasers, Dr. Coleman has built a flexible and versatile laser. In its original configuration, the equipment (Fig. 2) used a 4-meter cylindrical glass resonator with a 4-inch internal diameter. The resonator was excited by two modulators, each capable of exciting half the tube individually or the whole tube in unison. Each modulator delivered d-c pulses of 16,000 volts at 300 amperes for a duration of 5 microseconds at a variable repetition rate of from 20 to 400 pulses per second. Two spherical mirrors were used as oscillation terminals. Each mirror had a 4-meter radius of curvature, and their axes were colinear with the resonator axis. The radiation was coupled out of the resonator through a 2-millimeter hole drilled through the center

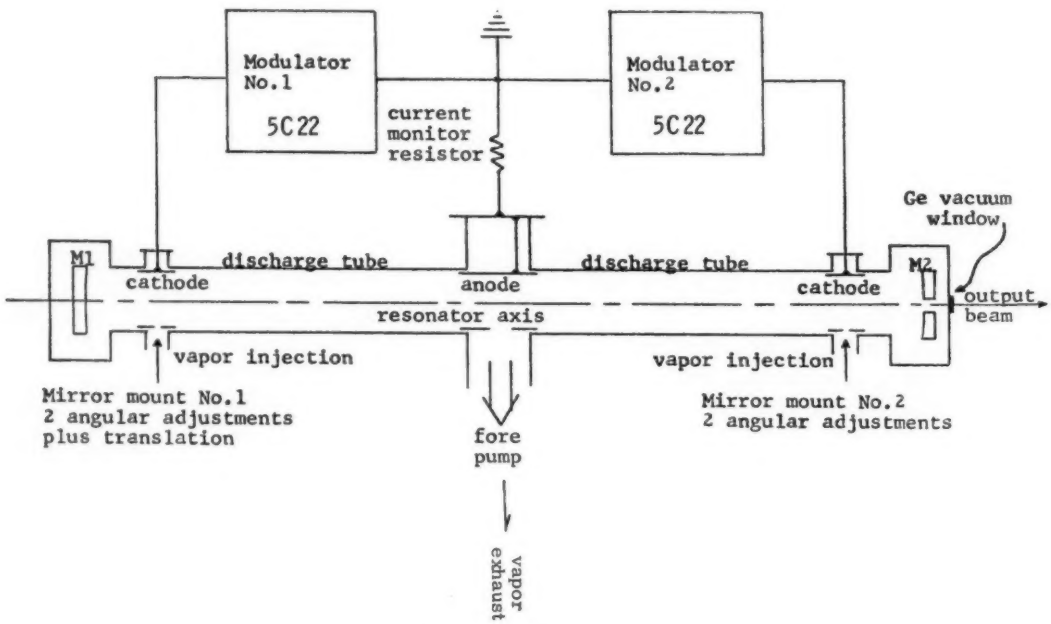


Figure 2. Water-vapor laser.

of one mirror. The output radiation was coupled into a gallium-doped germanium photoconductive detector. The laser output was analyzed by a 500-millimeter monochromator which has a resolution of 1 micron, and wavelength accuracy of one tenth of a micron.

FIR Suppression

To attain suppression, Dr. Coleman has replaced the adjustable mirror with a diffraction grating (Fig. 3), and used an effective resonator length of 236 centimeters while the rest of the equipment remains the same. The grating is an aluminum-coated, ruled material. The corrugated surface of the grating favors the oscillation of a particular wavelength. Only the selected wavelength is reflected from the grating to return along the resonator axis. All other wavelengths are scattered off-axis. The grating is adjustable, i.e., the laser can be "tuned" to a particular frequency. In this way the experimental apparatus is frequency selective and capable of suppressing both cascade and competition processes.

The grating has successfully suppressed inexpedient radiation, proven to be an efficient method for refining the spectral output, and provided some unexpected results. Multi-wavelength oscillations in the resonator were eliminated, and repetitive pulse-to-pulse output powers were achieved. The singular monochromatic output enabled the observation of a time delay between the onslaught of the d-c discharge pulse and the initiation of the lasing action. The delay is readily measured and may be the key to understanding the chemical reaction that is taking place in the laser. For example, the data imply that the lasing specie has a relaxation time on the order of tens of microseconds. This limits the possible candidates for the lasing specie. A third benefit of FIR suppression was the definition of four new lines in the H_2O spectrum. This achievement was possible because of the elimination of the line-to-line interactions and the resultant augmented power outputs. The cleaner output provides the necessary definitive data for quantitative analysis. Data collected using the grating has eliminated the possibility that certain radicals were the lasing media. Currently, the data are qualitatively consistent with the hypothesis that the H_2O molecule is the lasing specie.

The concept of suppression offers a promising technique for power enhancement in

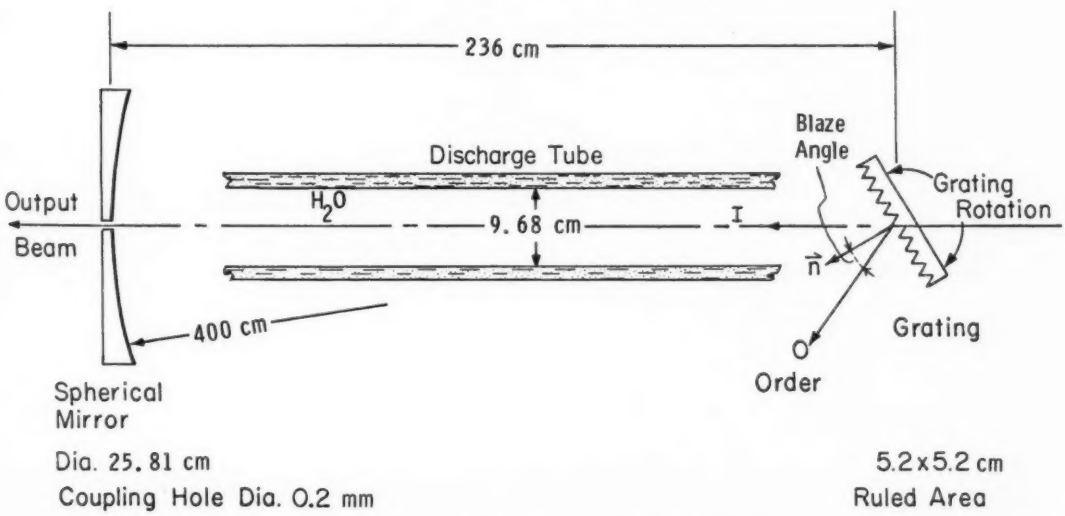


Figure 3. Resonator with diffraction grating.

the FIR, as well as molecular laser output filtering. This "tuning" capability might create applications for IR sources in a military environment. One possibility is that the grating might provide a method for frequency or amplitude modulation of a molecular laser. Dr. Coleman, under the sponsorship of AFOSR, is advancing the state-of-the-art in the use and understanding of the suppression mechanism. ☆

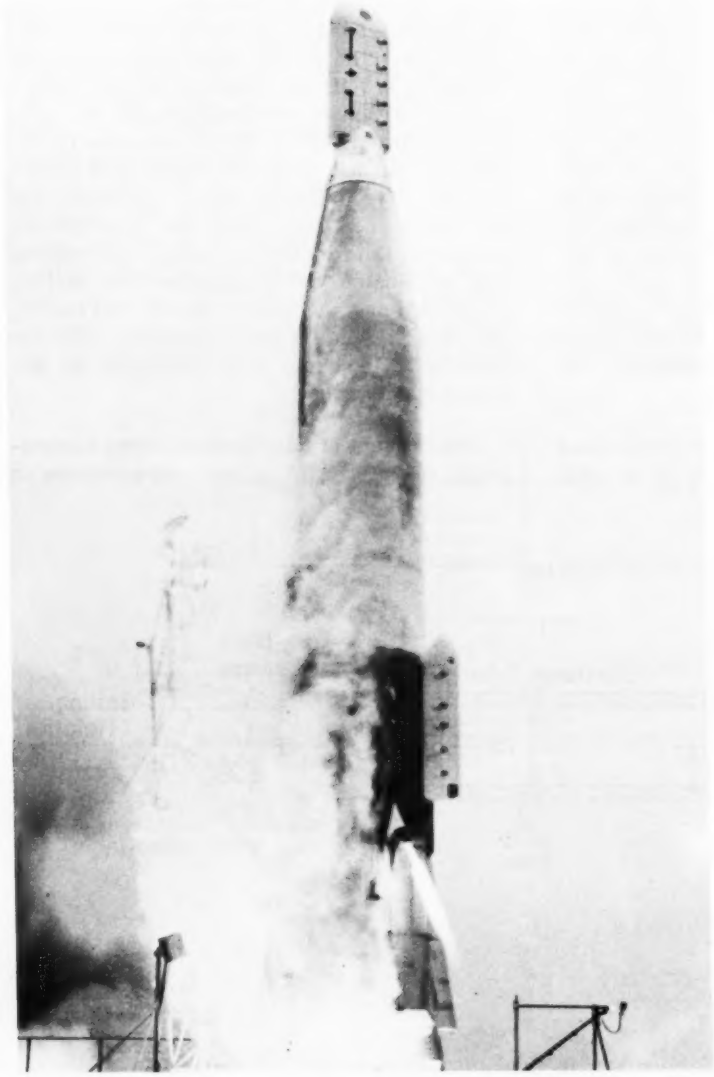
REFERENCES

(1) Coleman, P.D., "Water Vapor Gas Laser at 118 Microns," Proc. IEEE, 54, 577, April 1966.

(2) Coleman, P.D., "Spiking and Time Behavior of a Pulsed Water Vapor Laser," App. Phys. Letters, Vol. 10, No. 1, p. 7, 1 January 1967.

(3) Coleman, P.D., "Gas Laser Studies in the 100 to 1000 Micron Range," Activity Report, Grant SREE/AFOSR 804-66, December 1966.

(4) Jeffers, W.Q. and P.D. Coleman, "Status of Research on the H_2O Laser," Interim Report, Contract SREE/AFOSR 804-66, January 1967.



In January 1968 the OV 1 Program will be three years old. Shown is the latest OV 1 launch.